



# Trends in Deep Convective Clouds

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**28 February 2006**

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## **Outline**

### **→ Introduction**

**What do we define as a Deep Convective Cloud (DCC)  
and where are they located ?**

**Spectral characterization of DCC**

**Physical characterization of DCC**

**Statistical evaluate of DCC as function of day/night/land/ocean/latitude  
using AIRS data from the past three years.**

**Extension of the statistical analysis to 1978 using HIRS data**

**Conclusion**



This effort was motivated by two related questions:

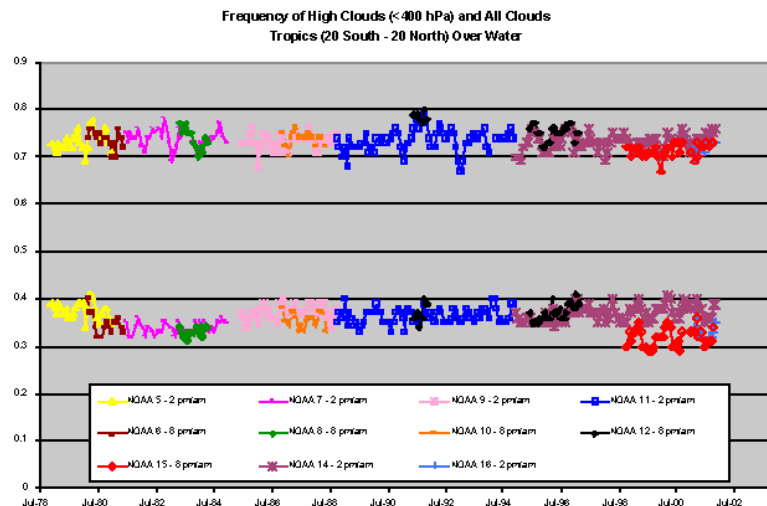
- 1) How can we connect AIRS to the available body of data to address climate questions
- 2) How can the climate quality of the data produced by an infrared sounder be established



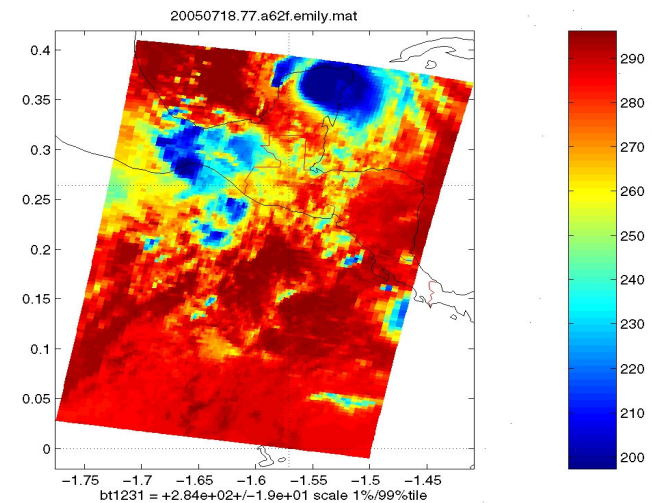
This effort started by looking at two pictures

UW 20 year Cloud  
Climatology  
AMS 2005 Poster

Hurricane Emily using  
AIRS 1231 cm-1



11 HIRS instruments

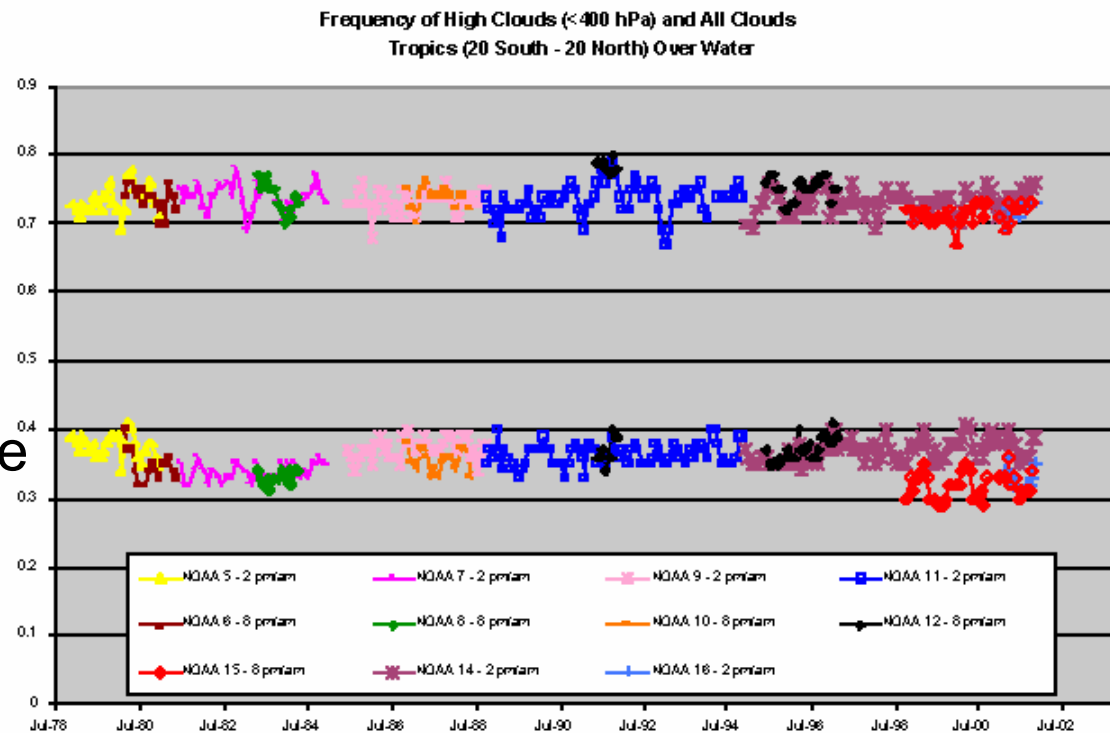


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2005 UW analysis shows all cloud cover very stable in the tropics

35% of the  
footprints have  
“high” clouds



Conclusions from HIRS CO<sub>2</sub> Observations of Tropical (20N-20S) Cloud Cover over Ocean

• All cloud cover is very stable

\* Clouds are detected in 75% of HIRS observations

\* N15 is out of family (HIRS 3) starting 1998



Science, Feb 1, 2002

## CERES/ERBE 22 year trend analysis

### **FEWER CLOUDS FOUND IN TROPICS**

#### **NASA scientists discover new evidence of climate change**

After examining 22 years of satellite measurements, NASA researchers find that more sunlight entered the tropics and more heat escaped to space in the 1990s than in the 1980s. Their findings indicate less cloud cover blocked incoming radiation and trapped outgoing heat.

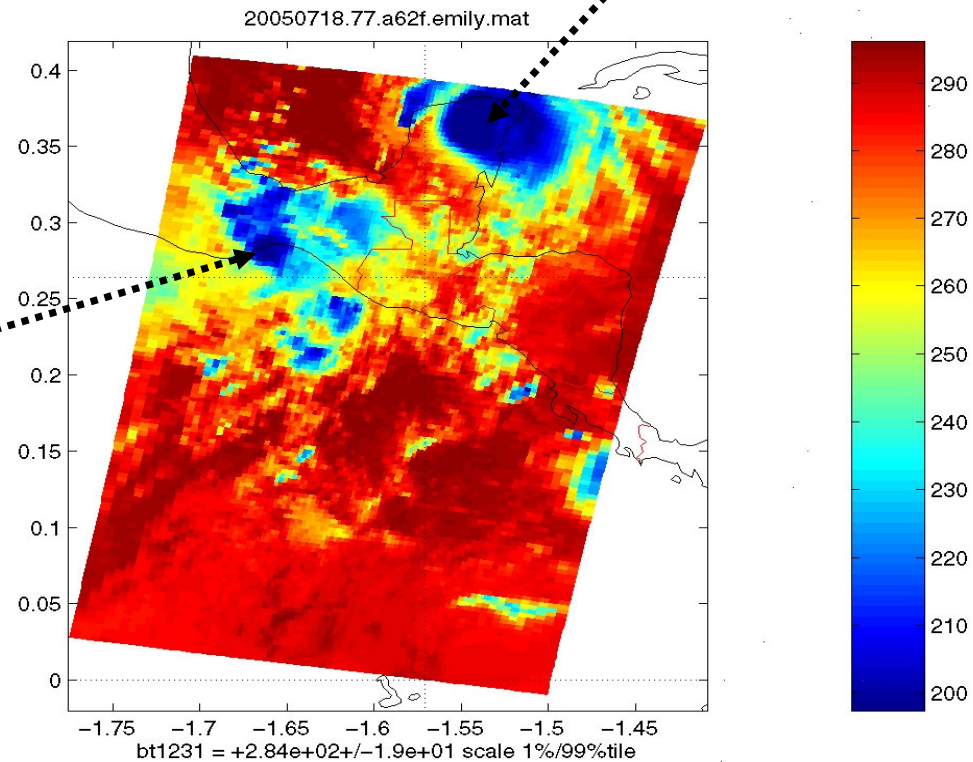
"Since clouds were thought to be the weakest link in predicting future climate change from greenhouse gases, these new results are unsettling," said Dr. Bruce Wielicki of NASA Langley Research Center, Hampton, Va. Wielicki is the lead author of the first of two papers about this research appearing in the Feb. 1, issue of "Science."

"It suggests that current climate models may, in fact, be more uncertain than we had thought," Wielicki added. "Climate change might be either larger or smaller than the current range of predictions."



Hurricane Emily

Deep  
Convective  
Clouds



Hurricanes and deep convective clouds differ more in scale than in their IR characteristics



## Deep Convective Clouds in the literature

Lindzen et al.(2001) hypothesis

Lin et al (2002) DCC correlation with SST

Chambers et al. (2002) CERES analysis

Hartmann & Michelson (2002) Constant anvil hypothesis

Del Genio & Kovari (2002) TRMM analysis

Lin et al (2004) decadal ERBS analysis





According to the CERES website

*“Deep convective clouds, such as those associated with thunderstorms, have neither a warming nor a cooling effect because their cloud greenhouse effect, although large, is nearly balanced by the effect due to the convective cloud high albedo”.*

*“The outgoing infrared spectra of high, cold, optically thick clouds were fairly representative of blackbody emission.”*

**The first statement is probably wrong.**

**We will show that the second statement is definitely wrong**



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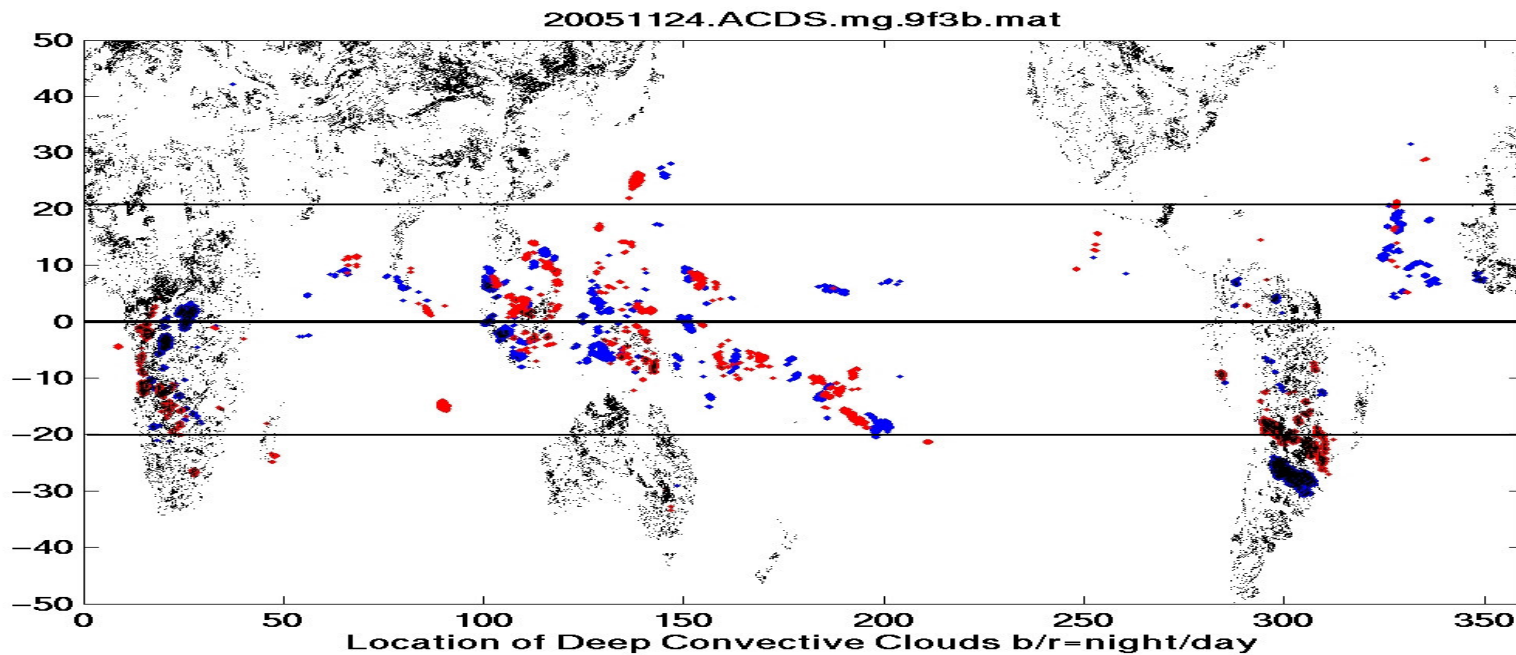


**A deep convective clouds is any structure which causes the brightness temperature over non-frozen land or ocean in the 13 km AIRS footprint to be less than 210 K in the 1231 cm<sup>-1</sup> window channel.**

**Other instruments use similar definitions, CERES requires that the broadband 10 micron channel brightness temperature be less than 218 K, Some studies require association with rain cells (TRMM/CERES)**



**Deep Convective Cloud are found almost exclusively within  $\pm 20$  degree from the equator. For 1:30 polar orbit there is little day (red points)/night (blue points) difference.**



The black dots are land clear footprints in the ACDS file



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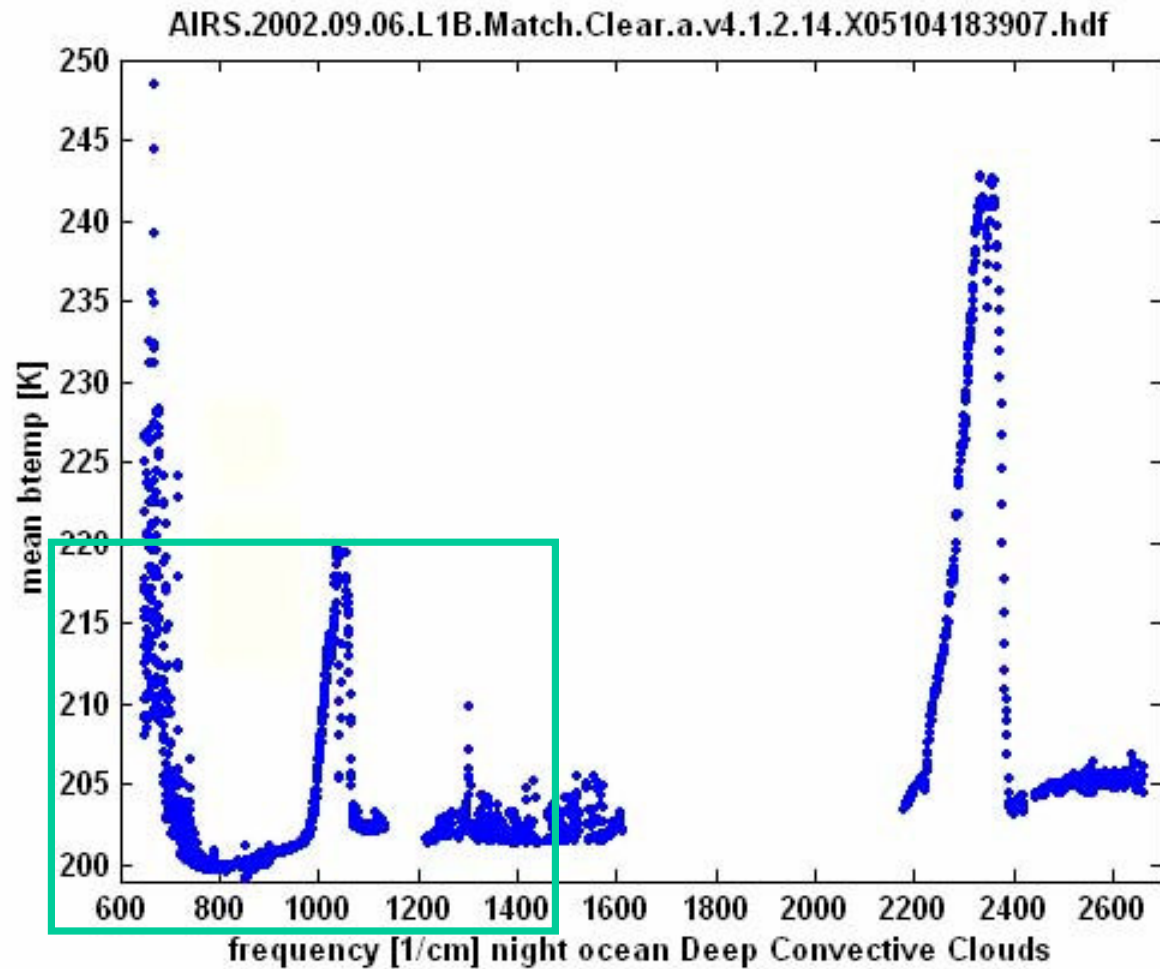
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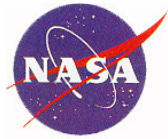
**Conclusion**



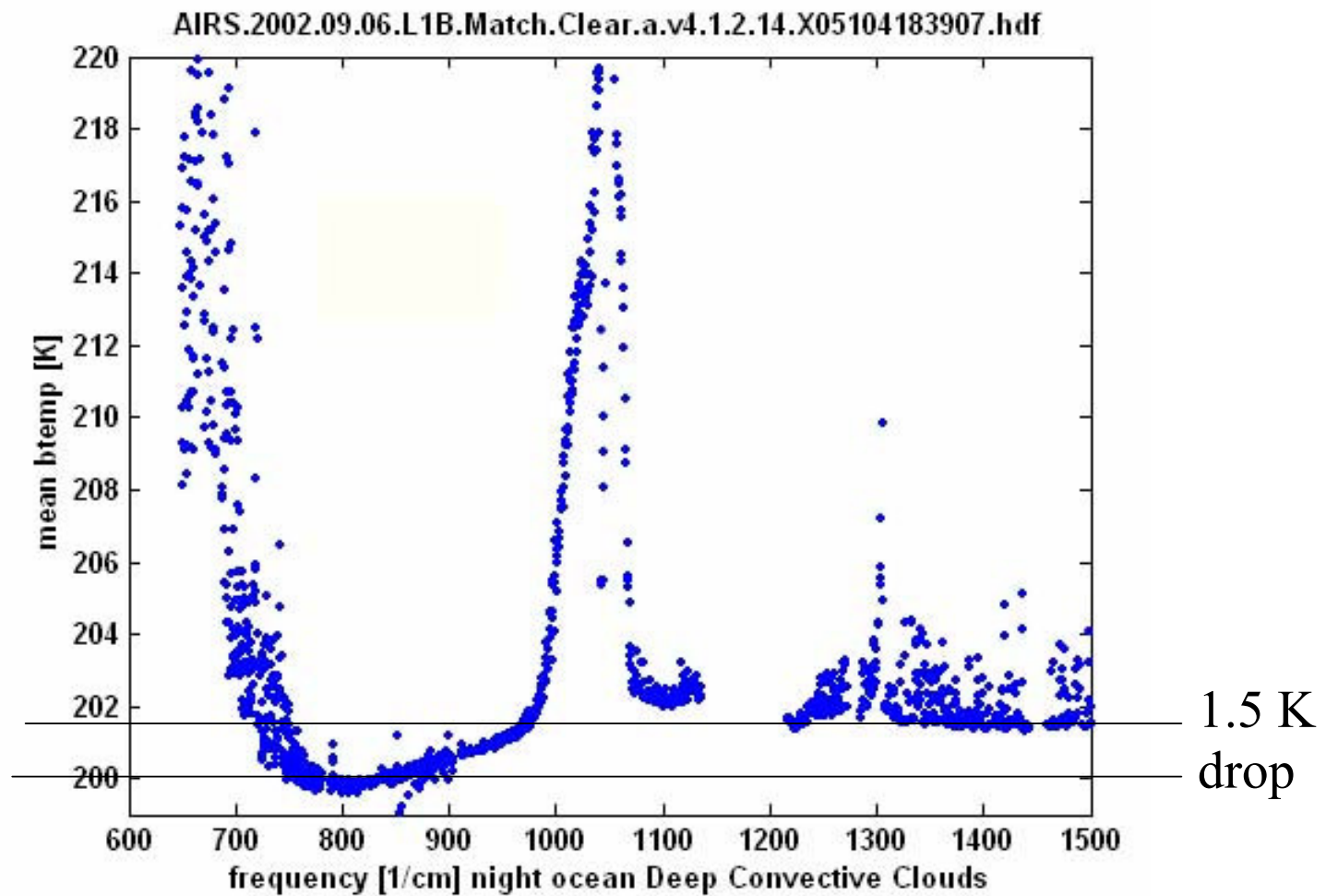
The spectra of DCC are dominated by stratospheric emission



*next we zoom in  
on 600-1500 cm<sup>-1</sup>*

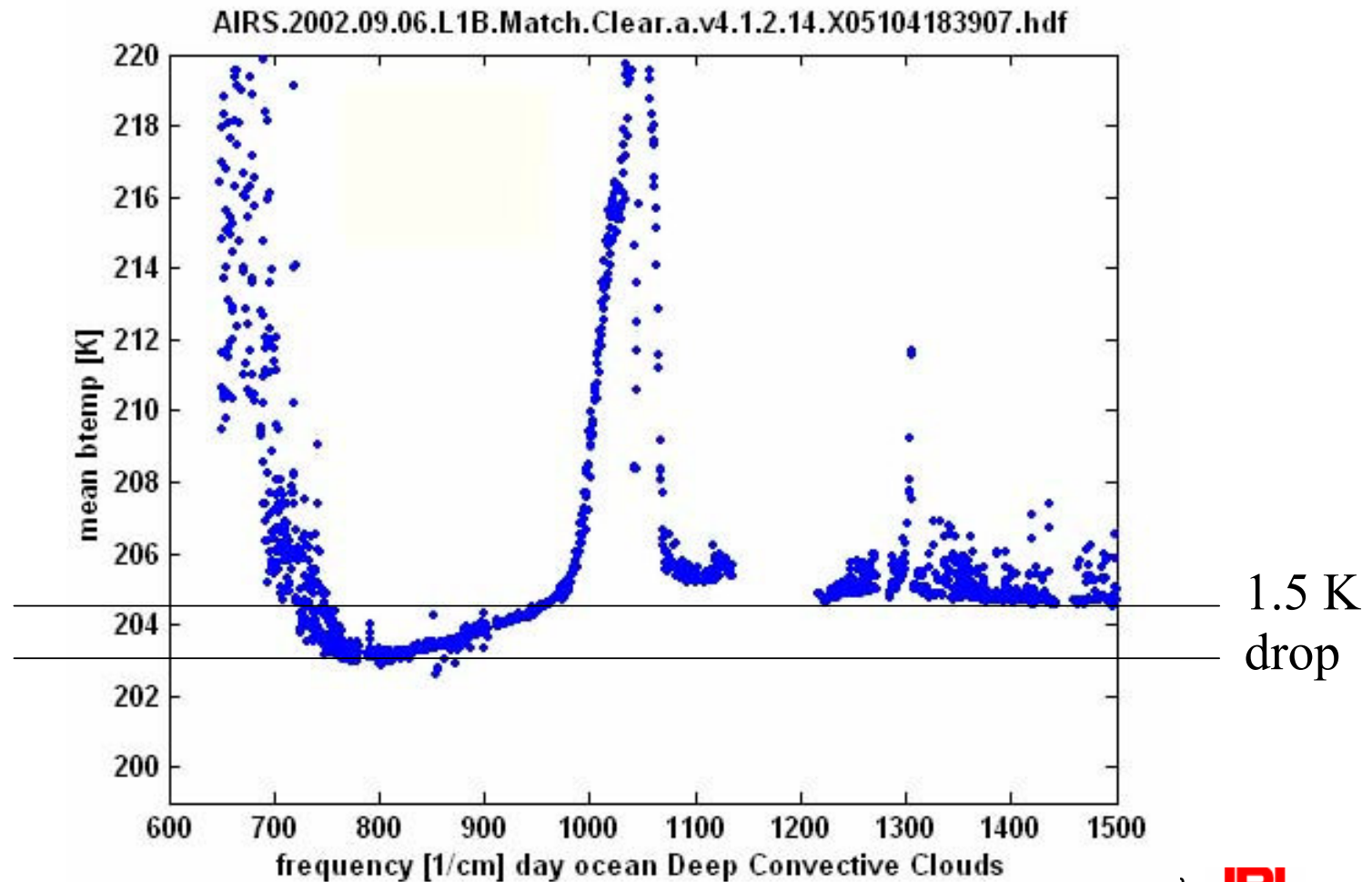


The threshold for DCC is 210K at 1231cm<sup>-1</sup>,  
but the mean at night is closer to 202K





The threshold for DCC is 210K at 1231cm<sup>-1</sup>,  
but the daytime mean is closer to 202K







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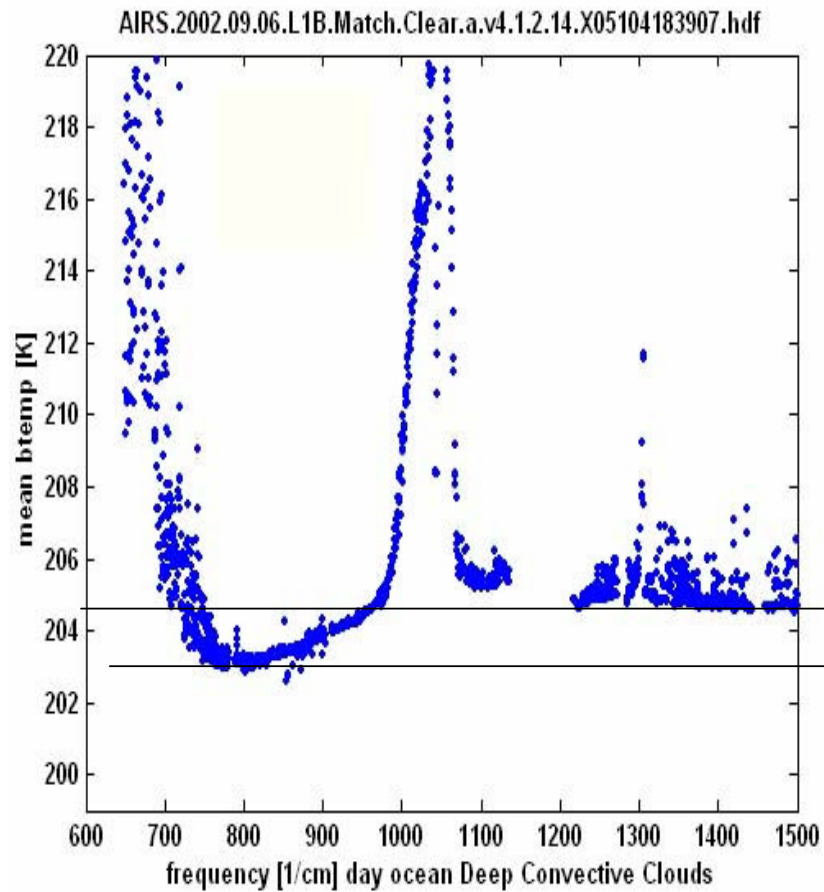
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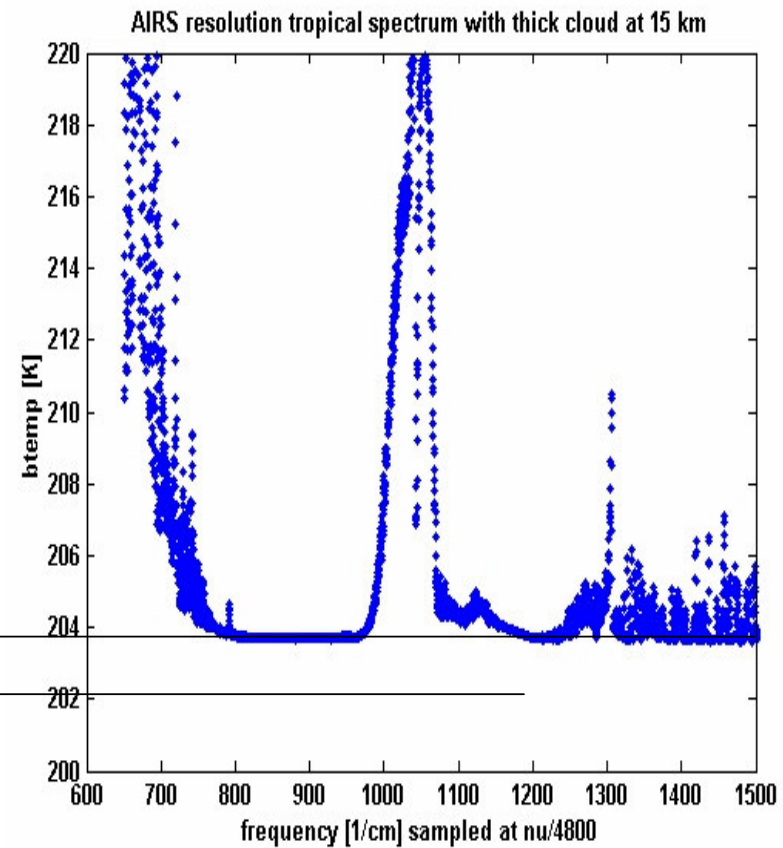
**Conclusion**



observed DCC spectrum



calculated tropical spectrum  
with e=1 cloud top at 15 km



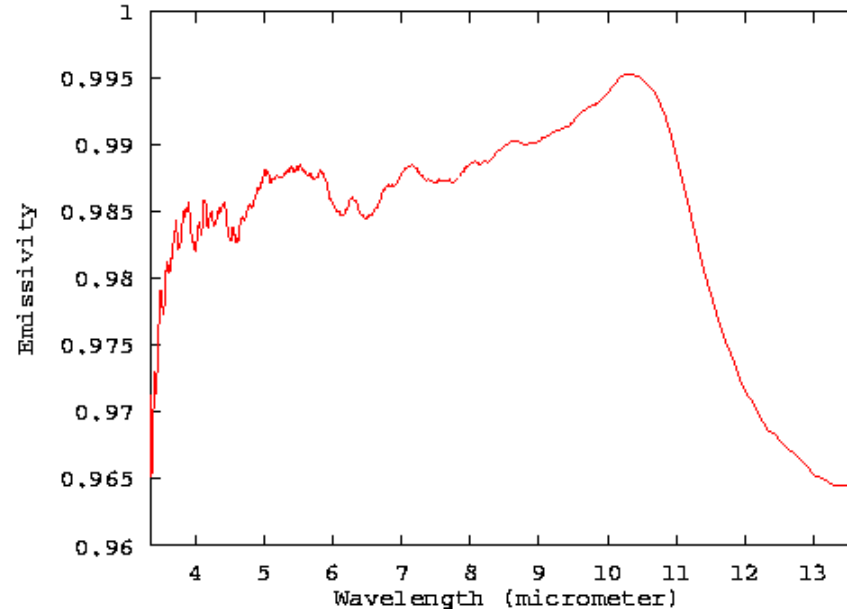
no 1.5 K drop

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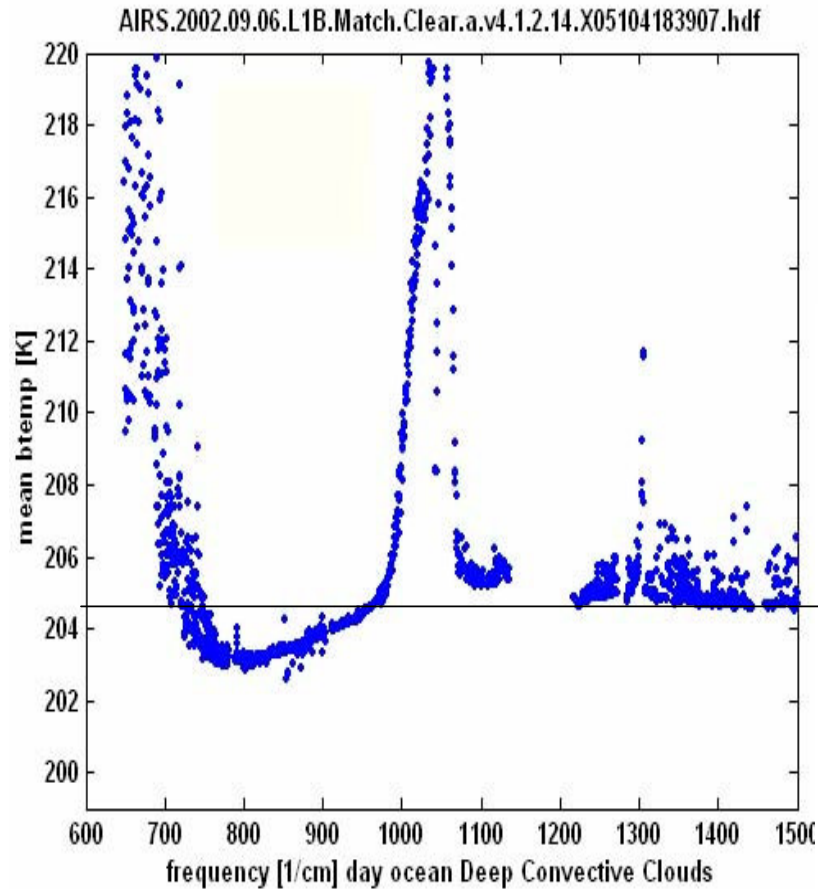
The 2 K drop in brightness temperature between 950 and 790  $\text{cm}^{-1}$  is equivalent to a 5% drop in emissivity, suggesting small ice particles.

Sample 1 - Emissivity of Ice Snow - Average of 3 Sets (Mammoth Lake:

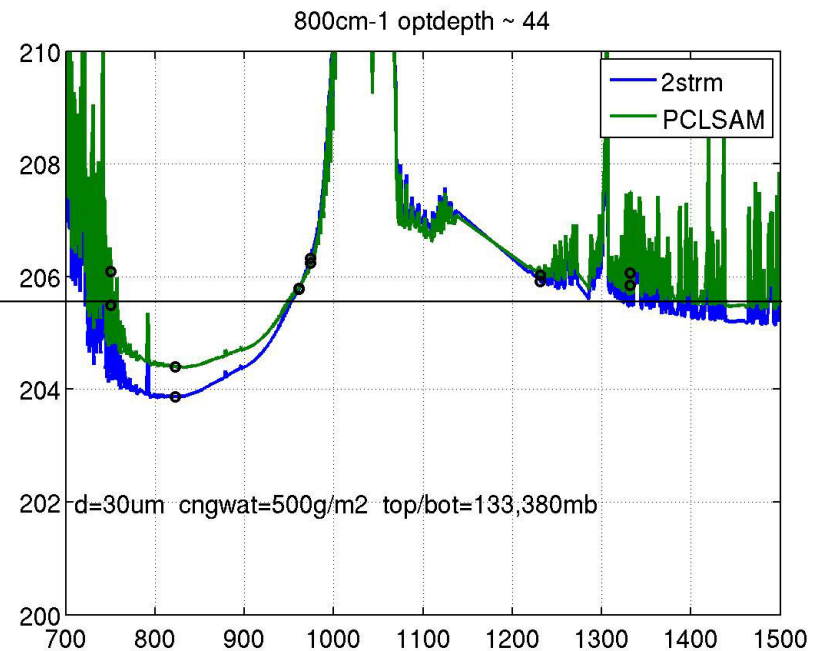




## observed DCC spectrum



Two scattering programs:  
Same tropical spectrum  
with cloud top at 133 mb and  
30 micron ice particles.  
Both produce a spectral drop



PCLSAM is a better fit **JPL**



**The first attempt at a physical cloud top characterization uses**

**p.cpsize = 30  $\mu$ m (diameter)**

**p.cngwat = 500 g/m<sup>2</sup>**

**p.cprtop = 133 mb**

**p.cprbot = 380 mb**

**BARAN\_ICE\_AGGREGATES were the ice crystal habit**

**Two scattering programs with these parameters give similar results**

**More work in progress to get a better fit in time for the  
SPIE San Diego meeting in August 2006. and  
Stockholm in September 2006**



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Tentatively we are looking at the statistics of

the fraction of the footprints which are DCC

the mean cloud top temperature

the mean drop between 1231 and 790 cm-1

the fraction of DCC outside +/-20 degree latitude

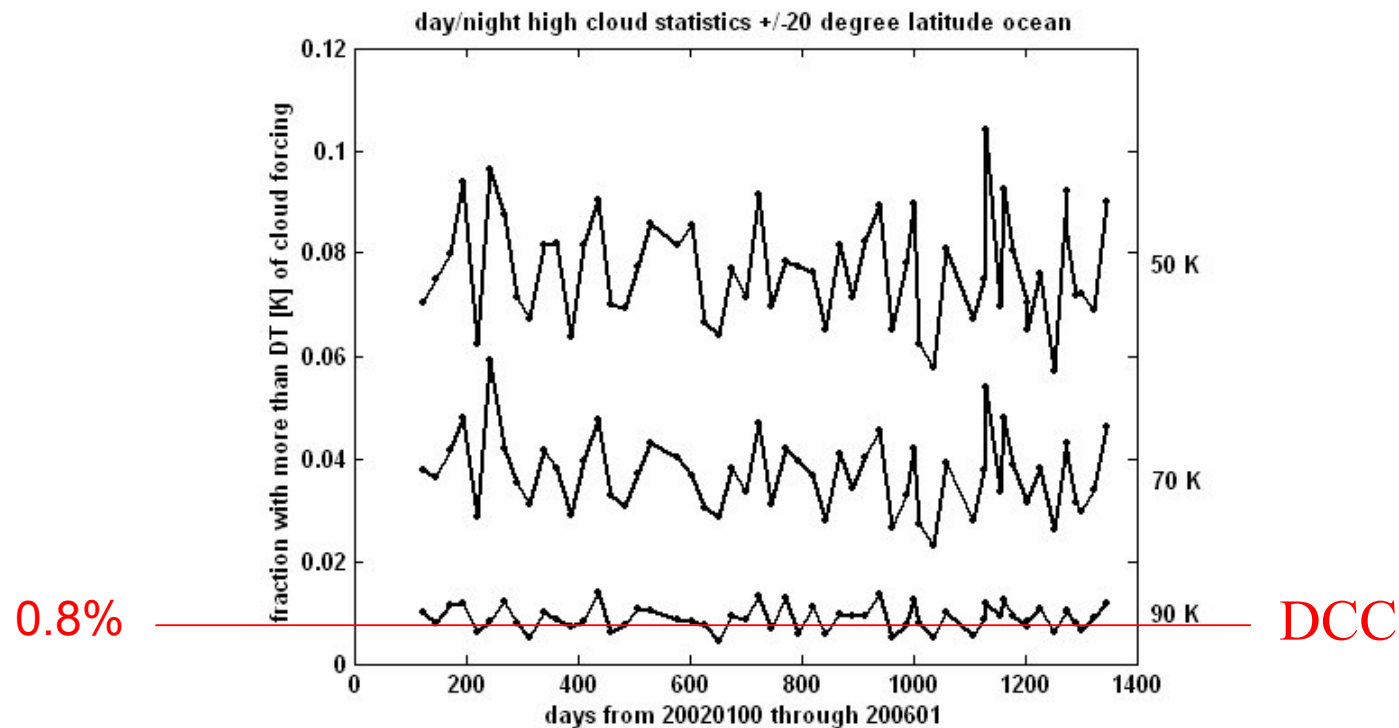
the cluster size

as function of day/night/land/ocean

tropical warm pool/atlantic



**Three years of AIRS data:  
Fraction of AIRS footprints with 50 K, 70 K and 90 K cloud forcing  
for +/-20 degree latitude day and night ocean has been very stable**



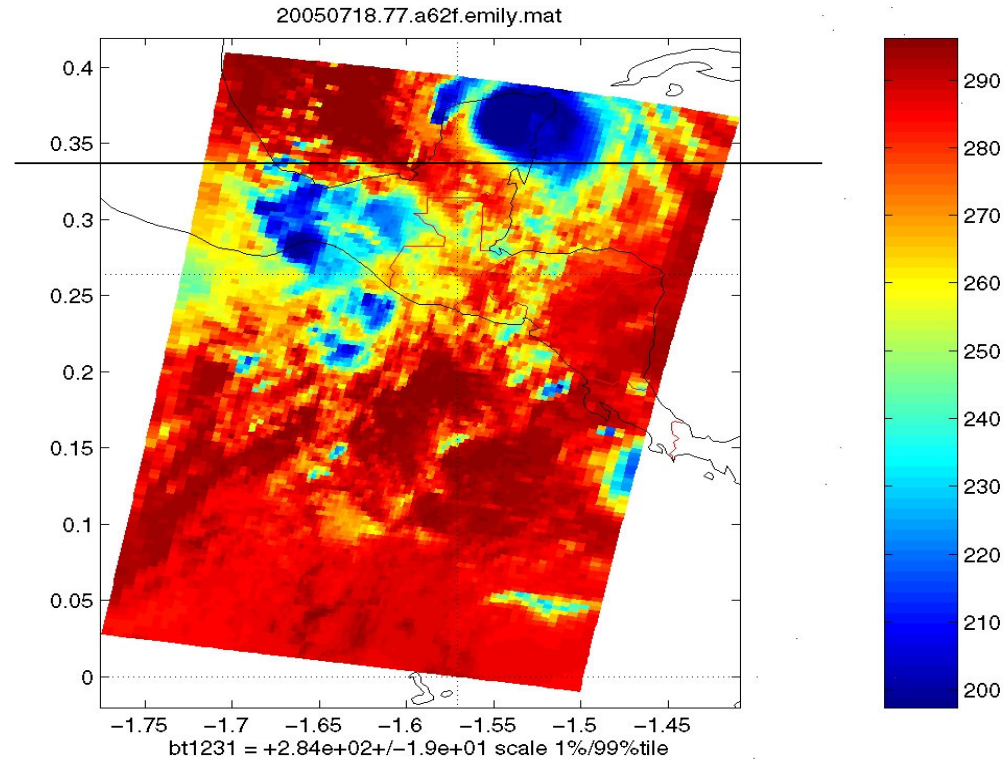
**0.8% of the AIRS footprints over +/-20 degree latitude  
day and night global ocean are identified as DCC**





The image of bt1231 for the granule from 20050718 at 2 AM  
when hurricane Emily entering the Yucatan peninsula

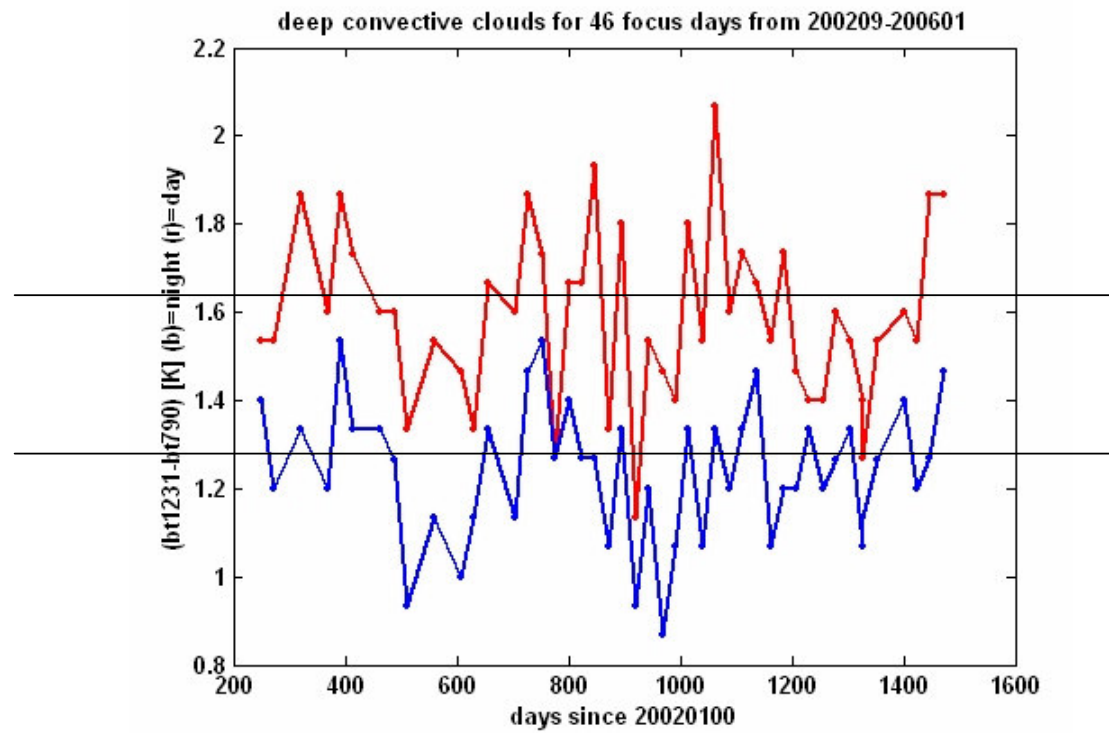
20 degree  
latitude



For this granule 429 ( 3.5%) of the footprints in the granule are identified as DCC,  
60% of the DCC are directly associated with the hurricane.



The daytime drop between bt1231 and bt790 is consistently larger than at night



Smaller particles ?



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Using three years of AIRS data shows no trends in the tropical latitudes for global oceans

What about trends

outside those latitudes  
in selected regions, i.e. Atlantic Warm Pool  
and longer time span

Can the AIRS data be connect up to the HIRS record which goes back to 1978 to look for trends

What about the IRIS FTS data from 1971?



**We are using the HIRS on NOAA 16 and NOAA 18  
to explore the issues in extending the DCC analysis.  
Issues include**

**Absolute calibration accuracy at low temperatures  
Spectral pass band uncertainties  
footprint size and footprint spacing difference  
ascending node differences**

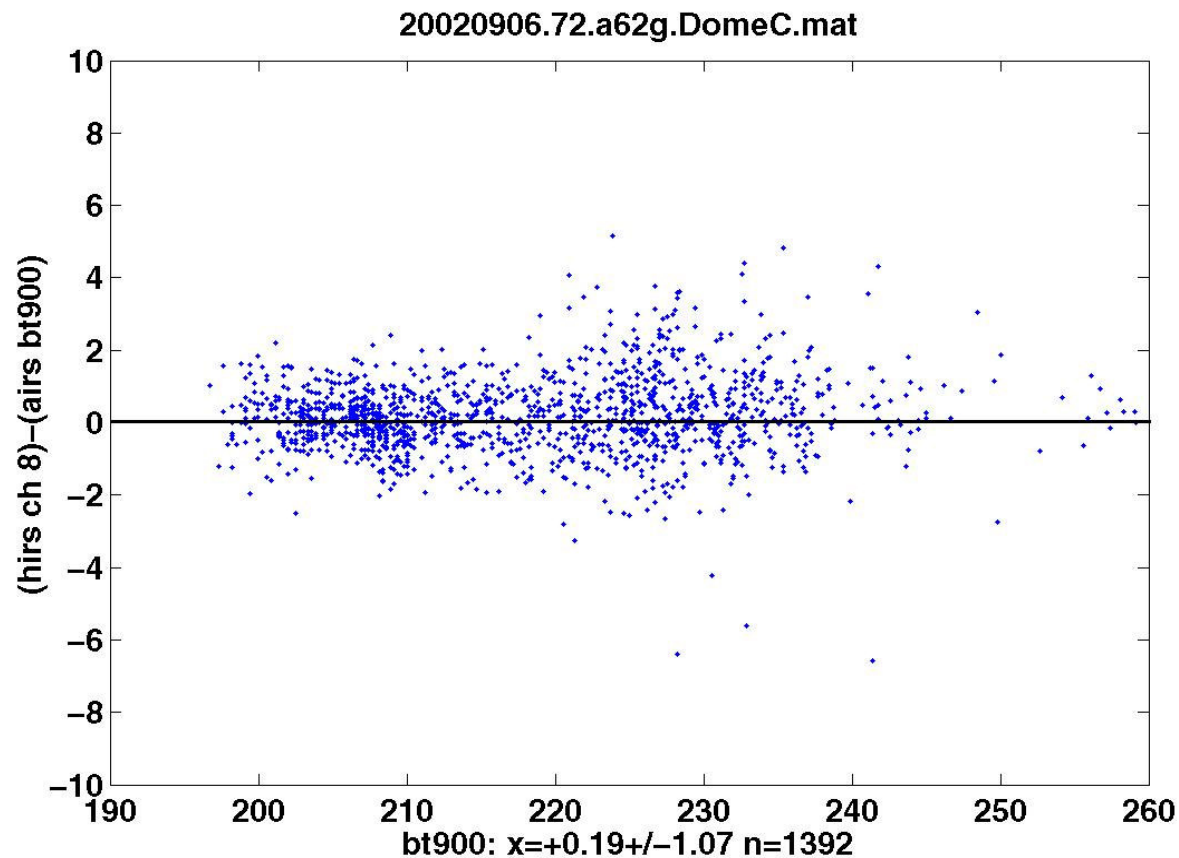
**Like AIRS, HIRS is a simple two-point calibrated radiometer**

**Example of HIRS-AIRS on NOAA 16 for an Antarctic granule  
shows the calibration at low temperature for HIRS  
may not be a major issue.**



The spot check of the absolute calibration of AIRS and HIRS on NOAA 16 at low temperature looks very good.

$$\text{HIRS.900cm}^{-1} - \text{AIRS.900cm}^{-1} = +0.19 \text{ K for } 200 < T < 240 \text{ K}$$



More on HIRS-AIRS at the calibration sessions on Friday

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The next step is to compare align AIRS and HIRS

DCC footprint fraction from HIRS (NOAA16)  
DCC footprint fraction from HIRS (NOAA18)

The big steps still to be evaluated are

IMG data from 1994 ?  
DCC statistics 30 years back with HIRS ?  
IRIS data from 1971 ?



This is work in progress

We first have to understand results from HIRS on NOAA16  
and NOAA 18 with the help of AIRS

More will be presented at the August 2006 SPIE meeting





## Summary and Conclusions

The analysis of DCC will be interesting in connection with

the frequency and size of severe storms  
correlation between hurricanes and Atlantic Warm Pool DCC

maybe global warming using the 30 year HIRS record

There are various issues which need to be resolved  
to make a credible analysis using HIRS data back to 1978

Similar issues exist in extending the DCC analysis  
using future sounders like IASI and CRIS.



Thanks for your attention





## 20020906 DomeC matchup

mstats(bt8(ve1)); % 900 cm-1 HIRS#8

197.2996+/- 2.4700 [ 193.091 203.750 ] 59 pts

mstats(bt900s(ve1)); % AIRS

197.2931+/- 2.4333 [ 192.467 205.133 ] 263 pts

bt10=bt(:, :, 10); % 802 cm-1 HIRS#10

mstats(bt10(ve1));

197.4301+/- 2.4850 [ 193.330 203.845 ] 59 pts

mstats(bt799s(ve1)); % AIRS

197.5443+/- 2.5333 [ 193.467 205.400 ] 263 pts

mstats(bt19(ve1)); HIRS# 19 is 2610-2710 cm-1

201.8754+/-16.9055 [ 194.082 262.211 ] 59 pts

mstats(bt2616s(ve1)); AIRS

201.8012+/-22.3333 [ 192.099 254.133 ] 263 pts

The agreement with AIRS is excellent

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